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DESCRIPTION

ELECTRIC POWER STEERING DEVICE

TECHNICAL FIELD

[0001] The present invention relates to an electric power steering device which generates a steering assist force by an electric motor.

BACKGROUND ART

[0002] Automotive electric power steering devices (EPS) employ a speed reduction apparatus. A column-type electric power steering device, for example, is adapted to reduce the rotation speed of an output shaft of an electric motor through a worm shaft and a worm wheel to amplify the output of the electric motor and transmit the output to a steering mechanism, thereby providing torque assist for a steering operation.

[0003] In general, a cylindrical joint which connects the output shaft of the electric motor to the worm shaft provides spline-coupling to an end of the worm shaft. The spline-coupled portion has a slight play defined in a rotation direction, so that noise occurs due to rattling attributable to the play.

[0004] To cope with this, an electric power steering device is provided in which an output shaft of an electric motor is coupled to a worm shaft via a joint including an elastic member for power transmission (see, for example,

Japanese Unexamined Patent Publication No. 2002-145083 disclosed by Japanese Patent Office on May 22, 2002).

[0005] The elastic member is disposed between a pair of co-rotatable iron engagement members at opposed ends of the output shaft and the worm shaft with an interference. If the interference is great, it is difficult to fix the elastic member between the engagement members, and a loss torque due to frictional resistance is increased to deteriorate a steering feeling.

[0006] On the other hand, if the interference is small, the elastic member is worn during prolonged use, so that gaps are formed between the elastic member and the engagement members. Therefore, the joint has plays defined in a rotation direction due to the gaps. As a result, noise and torque transmission variation occur to deteriorate the steering feeling.

[0007] Further, the respective components have different dimensional tolerances, making it very difficult to properly determine the interference.

[0008] It is an object of the present invention to provide an electric power steering device which is easier to assemble, has a relatively small loss torque, and suppresses rattling and noise for a long period of time.

DISCLOSURE OF THE INVENTION

[0009] To achieve the aforesaid object, an electric

power steering device according to a preferred embodiment of the present invention comprises a steering assist electric motor having an output shaft, a speed reduction mechanism including an input shaft disposed coaxially with the output shaft of the electric motor, and a power transmission joint which couples the output shaft of the electric motor to the input shaft of the speed reduction mechanism for power transmission. The power transmission joint includes an annular first engagement member co-rotatably connected to the output shaft of the electric motor, an annular second engagement member co-rotatably connected to the input shaft of the speed reduction mechanism, and an elastic member disposed between the first and second engagement members for transmitting a torque between the first and second engagement members. The elastic member includes an annular main body, and a plurality of engagement arms provided at a predetermined interval circumferentially of the main body as extending radially from the main body. The first and second engagement members each include a plurality of engagement projections engaged with the respective engagement arms of the elastic member circumferentially of the main body. The engagement arms of the elastic member each include a pair of power transmission faces, which are engaged with power transmission faces of corresponding engagement

projections of the first and second engagement members with interferences. The power transmission faces of the engagement arms include power transmission faces each having a relatively great interference and power transmission faces each having a relatively small interference.

[0010] According to this embodiment, the power transmission faces of the engagement arms include the relatively small interference power transmission faces, so that the elastic member can be easily fixed between the first and second engagement members. Further, the elastic member easily accommodates centering offset and angular offset between the first and second engagement members, and suppresses an increase in loss torque occurring due to the frictional resistance during the rotation, thereby improving the steering feeling.

[0011] In addition, even if the engagement arms of the elastic member are flattened during prolonged use, the relatively great interference power transmission faces still have sufficient interferences. Therefore, the torque transmission is mainly achieved through the power transmission faces still having the sufficient interferences. As a result, the noise and the torque transmission variation can be suppressed for a long period of time.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a schematic diagram illustrating the schematic construction of an electric power steering device according to one embodiment of the present invention;

Fig. 2 is a sectional view of major portions of the electric power steering device;

Fig. 3 is a sectional view taken along a line III-III in Fig. 2;

Fig. 4 is a perspective view of a biasing member for biasing an end of a worm shaft;

Fig. 5 is a sectional view taken along a line V-V in Fig. 2;

Fig. 6 is an exploded perspective view of a power transmission joint;

Fig. 7A is a front view of an elastic member in a non-restricted state, and Fig. 7B is a sectional view taken along a line 7B-7B in Fig. 7A;

Fig. 8 is a front view of an elastic member according to another embodiment of the invention;

Fig. 9 is a front view of a first engagement member according to further another embodiment of the invention;

Fig. 10 is a front view of a first engagement member according to still another embodiment of the invention;

Fig. 11 is a front view of a second engagement member

according to further another embodiment of the invention;

Fig. 12 is a front view of a second engagement member according to still another embodiment of the invention;

Fig. 13 is a perspective view of major portions of an elastic member according to further another embodiment of the invention; and

Fig. 14A is a front view of major portions of a first engagement member according to still another embodiment of the invention, and Fig. 14B is a front view of major portions of a second engagement member according to further another embodiment of the invention.

BEST MODE FOR IMPLEMENTING THE INVENTION

[0012] Embodiments of the present invention will hereinafter be described with reference to the attached drawings. Fig. 1 is a schematic diagram illustrating the construction of an electric power steering device including a power transmission joint according to one embodiment of the present invention.

[0013] Referring to Fig. 1, the electric power steering device 1 includes a steering shaft 3 connected to a steering member 2 such as a steering wheel, an intermediate shaft 5 connected to the steering shaft 3 via a universal joint 4, a pinion shaft 7 connected to the intermediate shaft 5 via a universal joint 6, and a rack bar 8 which has a rack tooth 8a meshed with a pinion tooth 7a provided around

an end portion of the pinion shaft 7 and serves as a turning shaft extending transversely of a motor vehicle. The pinion shaft 7 and the rack bar 8 constitute a rack and pinion mechanism A as a steering mechanism.

[0014] The rack bar 8 is supported in a linearly reciprocal manner in a housing 9 fixed to a body of the motor vehicle via a plurality of bearings not shown. Opposite ends of the rack bar 8 project laterally of the housing 9, and are respectively coupled to tie rods 10. The tie rods 10 are respectively coupled to corresponding steerable wheels 11 via corresponding knuckle arms (not shown).

[0015] When the steering member 2 is operated to rotate the steering shaft 3, the rotation is converted into the linear motion of the rack bar 8 transverse of the motor vehicle by the pinion tooth 7a and the rack tooth 8a. Thus, the turning of the steerable wheels 11 is achieved.

[0016] The steering shaft 3 is divided into an upper shaft 3a provided on an input side coupled to the steering member 2 and a lower shaft 3b provided on an output side coupled to the pinion shaft 7. The upper and lower shafts 3a, 3b are coaxially connected to each other via a torsion bar 12 in a relatively rotatable manner.

[0017] A torque sensor 13 is provided for detecting a steering torque on the basis of relative rotational offset

between the upper and lower shafts 3a and 3b via the torsion bar 12. The result of the detection of the torque by the torque sensor 13 is applied to an electronic control unit (ECU) 14. The electronic control unit 14 controls the driving of a steering assist electric motor 16 via a driving circuit 15 on the basis of the torque detection result, a vehicle speed detection result applied from a vehicle speed sensor not shown and the like. The speed of the output rotation of the electric motor 16 is reduced and transmitted to the pinion shaft 7 by a speed reduction mechanism 17. Further, the rotation is converted into the linear motion of the rack bar 8 for steering assist. The speed reduction mechanism 17 includes a worm shaft 18 as an input shaft rotatively driven by the electric motor 16, and a worm wheel 19 meshed with the worm shaft 18 and co-rotatably coupled to the lower shaft 3b of the steering shaft 3.

[0018] Referring to Fig. 2, the worm shaft 18 is disposed coaxially with an output shaft 20 of the electric motor 16. The worm shaft 18 has first and second end portions 18a, 18b axially spaced from each other, and a tooth portion 18c provided between the first and second end portions 18a and 18b.

[0019] The worm wheel 19 is coupled to an axially middle portion of the lower shaft 3b of the steering shaft 3 in

a co-rotatable manner with its axial movement prevented. The worm wheel 19 includes an annular metal core 19a co-rotatably coupled to the lower shaft 3b, and a synthetic resin member 19b fitted around the metal core 19a and having a tooth portion 19c provided circumferentially thereof. The worm wheel 19 is prepared, for example, by molding the synthetic resin member 19b from a resin with the metal core 19a inserted in a mold.

[0020] The first end portion 18a of the worm shaft 18 is coaxially connected for power transmission to an end of the output shaft 20 of the electric motor 16 opposed to the first end portion 18a via a power transmission joint 21 which is a feature of this embodiment.

[0021] The first and second end portions 18a, 18b of the worm shaft 18 are rotatably supported in a housing 17a of the speed reduction mechanism 17 via corresponding first and second bearings 22, 23. The first and second bearings 22, 23 are, for example, ball bearings.

[0022] Inner rings 24 and 25 of the first and second bearings 22 and 23 are respectively engaged co-rotatably with the first and second end portions 18a and 18b of the worm shaft 18. The inner rings 24 and 25 respectively abut against positioning steps 18d and 18e of the worm shaft 18 facing away from each other. Outer rings 26 and 27 of the first and second bearings 22 and 23 are

respectively retained in corresponding bearing retention holes 28 and 29 of the housing 17a of the speed reduction mechanism 17 in a non-rotatable manner.

[0023] The bearing retention hole 29 for the second bearing 23 is provided as a bias hole in which the second bearing 23 is held so as to be biased radially toward the worm wheel. An annular biasing member 30 is disposed between an inner peripheral surface of the bearing retention hole 29 and an outer peripheral surface of the outer ring 27 of the second bearing 23.

[0024] Referring to Fig. 3 (a sectional view taken along a line III-III in Fig. 2) and Fig. 4, the biasing member 30 includes a generally annular main body 31 having ends, a radial biasing portion 32 including a pair of resilient tongues respectively provided at the ends of the main body 31 as inclined in a staggered manner, and an axial biasing portion 33 including a plurality of inclined resilient tongues provided on a side edge of the main body 31.

[0025] Referring to Figs. 2 and 3, the radial biasing portion 32 is received by a reception recess 34 formed in an inner peripheral surface of the bearing retention hole 29, and the second end portion 18b of the worm shaft 18 is biased radially toward the worm wheel 19 via the second bearing 23 by a biasing force of the radial biasing

portion 32. Thus, backrush between the worm shaft 18 and the worm wheel 19 is eliminated.

[0026] Referring to Fig. 2, the axial biasing portion 33 is disposed between an end wall 17b of the housing 17a and an end face of the outer ring 27 of the second bearing 23 opposed to the end wall 17b, and supported by the end wall 17b to resiliently bias the worm shaft 18 axially toward the electric motor 16 via the second bearing 23.

[0027] On the other hand, the outer ring 26 of the first bearing 22 is axially positioned by a screw member 36 which is screwed into a screw hole 35 connected to the corresponding bearing retention hole 28 for preload adjustment and backrush adjustment. Thus, a biasing force of the axial biasing portion 33 simultaneously applies a preload to the first and second bearings 22, 23, and eliminates the backrush between the worm shaft 18 and the worm wheel 19.

[0028] Referring to Fig. 2, Fig. 5 (a sectional view taken along a line V-V in Fig. 2) and Fig. 6 (an exploded perspective view), the power transmission joint 21 will be described in detail. Referring first to Fig. 2, the power transmission joint 21 includes a first engagement member 41 co-rotatably connected to the outer shaft 20 of the electric motor 16, a second engagement member 42 co-rotatably connected to the first end portion 18a of

the worm shaft 18 as the input shaft of the speed reduction mechanism 17, and an elastic member 43 disposed between the first and second engagement members 41 and 42 for transmitting a torque between the engagement members 41 and 42. The first and second engagement members 41, 42 are composed of, for example, a metal. The elastic member 43 is composed of, for example, a synthetic rubber or a synthetic resin such as polyurethane.

[0029] Referring to Figs. 5 and 6, the elastic member 43 includes an annular main body 44, and a plurality of engagement arms 45 extending radially from the main body 44. As shown in Fig. 7A which illustrates the elastic member 43 in a free state not restricted by the first and second engagement members 41, 42, intervals of the engagement arms 45 defined between thicknesswise center lines 60 of the engagement arms 45 around the main body 44 (expressed by center angles a1, b1 about a center axis 430 of the elastic member 43) include relatively small intervals (corresponding to the center angles a1) and relatively great intervals (corresponding to the center angles b1).

[0030] The plurality of engagement arms 45 include engagement arms 45 each having a pair of power transmission faces 46, 46 facing opposite from each other circumferentially (X1) of the main body 44, and engagement

arms 45 each having a pair of power transmission faces 46, 460 facing circumferentially (X1) opposite from each other. As shown in Fig. 6 and Fig. 7B (a sectional view taken along a line 7B-7B in Fig. 7A), axially middle portions of the power transmission faces 46, 460 are each bulged into a chevron shape. As shown in Figs. 5 and 7A, the opposed power transmission faces 460 of each pair of engagement arms 45 defining the center angle a1 therebetween each have an increased interference as will be described later. That is, these power transmission faces 460 are relatively great interference power transmission faces each having a relatively great interference d1. The other power transmission faces 46 are relatively small interference power transmission faces each having a relatively small interference d2.

[0031] Referring to Fig. 7A, radially middle portions of the power transmission faces 46, 460 of the engagement arms 45 are each also bulged into a chevron shape. (The term "radially" means a direction in which the engagement arms 45 extend from the main body 44.)

[0032] Referring to Fig. 6, the first engagement member 41 includes an annular main body 51 having an engagement hole 49 for engagement with the output shaft 20, and a plurality of first engagement projections 55 projecting from a surface 53 of the main body 51 opposed to the second

engagement member 42, while the second engagement member 42 include an annular main body 52 having an engagement hole 50 for engagement with the worm shaft 18, and a plurality of second engagement projections 56 projecting from a surface 54 of the main body 52 opposed to the first engagement member 41.

[0033] The first engagement projections 55 of the first engagement member 41 have the same shape and size, and are equidistantly arranged circumferentially of the main body 51. The second engagement projections 56 of the second engagement member 42 have the same shape and size, and are equidistantly arranged circumferentially of the main body 52.

[0034] In the power transmission joint 21 in an assembled state as shown in Fig. 5, the first and second engagement projections 55, 56 of the first and second engagement members 41, 42 are arranged in circumferentially alternate relation, and the corresponding engagement arms 45 of the elastic member 43 are held between the circumferentially adjacent first and second engagement projections 55 and 56. In other words, the first and second engagement projections 55, 56 are meshed with the engagement arms 45 by holding the corresponding engagement arms 45 of the elastic member 43 between the circumferentially adjacent first and second

engagement projections 55 and 56.

[0035] As shown in Figs. 5 and 6, the first and second engagement projections 55 and 56 respectively have power transmission faces 57 and 58 each associated with the power transmission face 46 or 460 of the corresponding engagement arm 45 of the elastic member 43.

[0036] According to this embodiment, when the engagement arms 45 of the elastic member 43 and the first and second engagement projections 55, 56 of the first and second engagement members 41, 42 are combined together as shown in Fig. 5, the power transmission faces 460 of the engagement arms defining the relatively small center angle a1 therebetween each have the relatively great interference d1, and the other power transmission faces 46 each have the relatively small interference d2.

[0037] Since the interferences of the power transmission faces 46 are not so great, it is easy to combine the elastic member 43 with the first and second engagement members 41, 42.

[0038] Further, the elastic member 43 easily accommodates centering offset and angular offset between the first and second engagement members 41 and 42. i.e., between the output shaft 20 and the worm shaft 18, and suppresses an increase in loss torque occurring due to the frictional resistance during the rotation, thereby

improving the steering feeling.

[0039] In addition, even if the engagement arms 45 of the elastic member 43 are flattened during prolonged use, the power transmission faces 460 of the engagement arms 45 each originally having the relatively great interference d1 still have sufficient interferences. Therefore, the torque transmission is mainly achieved through the power transmission faces 460 of the engagement arms 45. As a result, noise and torque transmission variation can be suppressed for a long period of time.

[0040] A gap of about 10μm, for example, may be provided between the positioning step 17c of the housing 17a and the outer ring 26 of the first bearing 22, and the worm shaft 18 may be biased axially by the biasing force of the elastic member 43. In this case, the elastic member 43 also contributes to the backrush adjustment.

[0041] In this embodiment, the intervals of the engagement arms 45 defined between the thicknesswise center lines 60 of the engagement arms 45 may differ from each other, so that the engagement arms 45 are arranged at different pitches.

[0042] In the present invention, it is merely necessary to provide the power transmission faces 460 each having the relatively great interference d1. Therefore, as shown in Fig. 8, the elastic member 43 in a free state not

restricted by the first and second engagement members 41, 42 may be configured such that the engagement arms 45 are arranged at the same interval defined between the thicknesswise center lines 60 thereof (corresponding to a center angle c1) and include engagement arms 451 each having a relatively great thickness e1 as measured in the circumferential direction X1 and engagement arms 452 each having a relatively small thickness f1. That is, e1>f1. In this case, the engagement arms 451 each having the relatively great thickness e1 each have a pair of power transmission faces 460 each having a relatively great interference.

[0043] In the embodiment of Fig. 8, the engagement arms 451, 452 are equidistantly arranged, but may be arranged at different intervals as in the embodiment of Fig. 7A.

[0044] As shown in Fig. 9, the first engagement member 41 may be configured such that intervals of the first engagement projections 55 defined between thicknesswise center lines 61 of the first engagement projections 55 (expressed by center angles g1, h1 about a center axis 410 of the first engagement member 41) include a relatively great interval (corresponding to the relatively great center angle g1) and relatively small intervals (corresponding to the relatively small center angles h1)

(i.e., g1>h1). Alternatively, as shown in Fig. 10, the first engagement member 41 may be configured such that the first engagement projections are arranged at the same interval defined between the thicknesswise center lines 61 thereof (corresponding to a center angle j1) and include a first engagement projection 551 having a relatively great thickness m1 as measured circumferentially of the first engagement member 41 and first engagement projections 552 each having a relatively small thickness n1.

[0045] In the embodiments of Figs. 9 and 10, the engagement arms 45 preferably have the same thickness, and are equidistantly arranged. Further, the engagement projections 56 of the second engagement member 42 preferably have the same thickness, and are equidistantly arranged.

[0046] As shown in Fig. 11, the second engagement member 42 may be configured such that intervals of the second engagement projections 56 defined between thicknesswise center lines 62 of the second engagement projections 56 (expressed by center angles p1, r1 about a center axis 420 of the second engagement member 42) include a relatively great interval (corresponding to the relatively great center angle p1) and relatively small intervals (corresponding to the relatively small center angles r1) (i.e., p1>r1). Alternatively, as shown in Fig.

12, the second engagement member 42 may be configured such that the second engagement projections 56 are arranged at the same interval (corresponding to a center angle w1) and include a second engagement projection 561 having a relatively great thickness y1 as measured circumferentially of the second engagement member 42 and second engagement projections 562 each having a relatively small thickness z1 (i.e., y1>z1).

[0047] In the embodiments of Figs. 11 and 12, the engagement arms 45 preferably have the same thickness, and are equidistantly arranged. Further, the engagement projections 55 of the first engagement member 41 preferably have the same thickness, and are equidistantly arranged.

[0048] In Fig. 9, the intervals of the first engagement projections 55 may differ from each other, so that the first engagement projections 55 are arranged at different pitches. In Fig. 11, the intervals of the second engagement projections 56 may differ from each other, so that the second engagement projections 56 are arranged at different pitches.

[0049] The present invention is not limited to the embodiments described above. For example, at least one power transmission face 46 of at least one engagement arm 45 may include a cam surface 46A, as shown in Fig. 13, which can be circumferentially compressed as the first

and second engagement members 41, 42 axially approach each other.

[0050] Further, as shown in Fig. 14A or 14B, at least one of the power transmission faces 57, 58 of the first and second engagement projections 55, 56 may include a cam surface 57A, 58A which can circumferentially compress the engagement arm 45 of the elastic member 43 as the first and second engagement members 41, 42 axially approach each other. The embodiments of Figs. 13, 14A and 14B are advantageous in that the elastic member 43 can assuredly be brought into circumferential press contact with the engagement projections 55, 56 when the elastic member 43 is axially compressed by the first and second engagement members 41, 42.

[0051] In the embodiments described above, the worm gear mechanism is used as the speed reduction mechanism, but any of other known gear mechanisms such as a bevel gear mechanism may be used. A rotation shaft of a driving gear of the bevel gear mechanism or the like gear mechanism may be used as the input shaft of the speed reduction mechanism.

[0052] While the present invention has been described in detail by way of the specific embodiments, skilled persons who have understood the foregoing will easily come up with variations, modifications and equivalents of the

embodiments. Therefore, the scope of the present invention is defined by the appended claims and their equivalents.

[0053] This application corresponds to Japanese Patent Application No. 2004-22118 filed with the Japanese Patent Office on January 29, 2004, the disclosure of which is incorporated herein by reference.